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ABSTRACT

A review of the literature reveals that obstacles to the successful transfer of basic skills, knowledge, and thinking skills during classroom instructional time differ depending on which of three components of expertise is entailed: conceptual understanding, domain-specific basic skills, or domain-specific strategies. This paper focuses on conceptual understanding and transfer, conceptual knowledge and problems of activation, lateral and vertical transfer of automated basic skills, rational task analysis, and strategy transfer. Curriculum and instructional implications are also discussed. (Contains 39 references.) (Author/SM)

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Teaching for Transfer: Classroom Instructional Implications

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Abstract

A review of the literature reveals that obstacles to the successful transfer of basic skills, knowledge, and thinking skills during classroom instructional time differ depending on which of three components of expertise is entailed: conceptual understanding, domain-specific basic skills, or domain-specific strategies. This manuscript, accordingly, focuses on conceptual understanding and transfer, conceptual knowledge and problems of activation, lateral and vertical transfer of automated basic skills, rational task analysis, and strategy transfer. Curriculum and instructional implications are also discussed.

Teaching for Transfer: Classroom Instructional Implications

Although the transfer of basic skills, knowledge, and thinking skills is integral to our educational aspirations and expectations, many students believe that little of what they learned in school benefited them later in life. Not surprisingly, transfer of learning—the application of skills and knowledge learned in one setting or under one set of conditions to another setting and/or under a different set of conditions—persists as one of the most vexing problems in the classroom (Bevevino, Dengel, & Adams, 1999; Borich & Tombari, 1997; Rossett, (1997). Cognitive and educational psychologists, however, have made notable progress over the past decade in understanding and surmounting some of the impediments to transfer. The picture currently emerging suggests that impediments to transfer differ depending on which of three components of expertise is entailed: (1) conceptual understanding, (2) domain-specific basic skills, or (3) domain-specific strategies (Gagne', Yekovich, & Yekovich, 1993, p. 235). Since the factors, which influence transfer, differ to some extent for these three components of expertise, each of these areas will be discussed separately.

Conceptual Understanding and Transfer

Consider two teachers: both have taught mathematics in high school for several years, and both have been asked to teach in elementary schools. From the outset of the new school year, each teacher realizes that several students are academically ill prepared. This realization forms the initial representation of these teachers' problems. Assume that what these representations lead both teachers to recall, from similar past experiences at the high school level, differs to some extent. It is very likely that these differences in activated knowledge will entail different solutions. More specifically, the teacher who understands that students at different grade levels require different remediation techniques will probably be more successful in solving the problem of academically ill prepared students. This scenario illustrates how the probability of successful transfer is contingent upon the quality of one's conceptual understanding of a problem (Hoffman, Crandall, & Shadbolt, (1998); Chmielewski & Dansereau, (1998). By now, researchers have repeatedly demonstrated this principle in a variety of domains, including generating and interpreting computer programs (Mayer, 1975), solving science problems (Bromage & Mayer, 1981), troubleshooting problems associated with mechanical

or electrical systems (Means, & Gott, 1988; Tenney & Kurland, 1988), and writing (Case & McKeough, 1990).

Studies Linking Conceptual Understanding and Transfer

Mayer (1975) provided two groups of students with different amounts of conceptual information for learning the FORTRAN programming language. Each student had to solve two types of problems:to generate a specific program and to interpret some new program statements. In addition, both types of problems reflected three levels of complexity:one-line statements, nonlooping programs, and looping programs. Results indicated that the rule group, which received the lesser amount of conceptual information, excelled at low transfer problems, whereas the model group excelled at problems requiring much transfer. The model group outperformed the rule group because their booklets provided them with a conceptual underpinning of the FORTRAN programming language, enabling them to relate new knowledge to prior conceptual knowledge.

Mayer's (1975) results, however, were plausible at best because a direct measure of students' conceptual understanding was initially lacking. This shortcoming was resolved in a later study (Mayer & Bromage, 1980) in which

half of the students were given a conceptual model before reading program statements, while half received it after. Unlike the previous study, however, once students finished reading their booklets, they were asked to recall the definition and explain all statements they had learned. The results obtained by students who studied the model before learning the program statements lend support to the belief that conceptual understanding facilitates breadth of transfer. Apparently, these students organized their knowledge around the functional concepts entailed by the model.

Conceptual Knowledge: The Paradoxical Nature of Activation

Merely possessing conceptual knowledge appropriate for a given problem-solving domain does not guarantee that such knowledge will be activated when useful for solving a novel problem (e.g., Perfetto, Bransford, & Franks, 1983). This paradox is perplexing and is far from being completely understood. Nonetheless, researchers are making progress. In addressing this issue, three main areas of research will be discussed: producing a problem-solving context, anchored instruction, and cognitive apprenticeship.

Producing a problem-solving context. Some researchers (Bransford, Vye, Knizer, & Risko, 1990; Brown, Collins, &

Duguid, 1989) believe that if students are to successfully activate conceptual knowledge in a problem-solving context, then they should learn this knowledge originally in a problem-solving context. Several studies (Adams, Kasserman, Yearwood, Perfetto, Bransford, and Franks, 1988; Bransford, et al, 1990; Perfetto, Bransford, and Franks, 1983) tested this belief by asking university students to solve a variety of verbal problems. When such problems were encoded in an arbitrary manner, the students were often unable to solve them; however, when the problems were encoded in a problem context, performance was significantly better because information pertinent to solving a problem was more easily recalled.

Anchored instruction. Bransford and his colleagues (Bransford et al, 1990) have focused on anchored instruction: a pedagogic approach, which provides students with opportunities to gain pertinent knowledge in the context of trying to solve complex, authentic problems. The Young Sherlock project, perhaps their most enterprising project, was designed to enable fifth graders to learn about language arts, science, and social studies. Over a seven-month period, students engaged in numerous activities after watching the Young Sherlock movie. Children in the project classrooms significantly

retained more vocabulary and factual information and composed more cohesive stories than children in control classrooms. Although this approach is promising, the degree or extent of transfer achieved is not known. Hopefully, the knowledge acquired by these children will transfer to various problem contexts; however, this knowledge may instead transfer to similar contexts, only (Gagne',Yekovich, & Yekovich, 1993).

Cognitive apprenticeship. Cognitive apprenticeship, like anchored instruction, places learners in a problem-solving context: The learner is treated like a novice who will be apprenticed to an expert (Collins, Brown, & Newman, 1989; Borich & Tombari, 1993—Marilyn's book). Using this type of instruction, Lampert (1986) had fourth graders participate in problem solving activities involving money. The students were able not only to understand the conceptual bases of multiplication algorithms but also to invent their own computational algorithms through skilful problem-solving discussions. Lampert's work is promising because although cognitive apprenticeship has well-documented effects on transfer of strategies (e.g., Palincsar & Brown, 1984), its impact on improving activation of conceptual knowledge is less well-documented (Gagne', Yekovich, & Yekovich, 1993).

Transfer of Automated Skills

Some of the relevant knowledge students identify for successfully solving a novel problem is frequently in the form of automated basic skills, which are represented in procedural form. Fortunately, these automated basic skills will not need to be re-learned for the novel problem, allowing for great savings in time, since proceduralization—a time-consuming process—is obviated for some of the skills inherent in the new solutions.

Transfer of Automated Basic Skills: Studies

Gagne's research (1965,1970) distinguishes between two forms of transfer: lateral and vertical. According to Gagne, lateral transfer--also referred to as load road transfer (Perkings and Salomon, 1988)--refers to the application of some known knowledge in a new context but at a level of complexity comparable to the old context. For instance, using the skills associated with driving a car to learn how to drive a truck is an example of lateral transfer. Vertical transfer, on the other hand--also known as high road transfer (Perkings and Salomon, 1988)--involves the use of known knowledge to acquire more complex knowledge, which embodies the known knowledge (Gagne, Yekovich, & Yekovich, 1993). In this type of transfer, lower-level skills often facilitate the acquisition of higher-level skills by contributing to and

functioning as prerequisites for them. In this section, the extent to which the source skill overlaps with the target skill, one of the most crucial conditions facilitating the lateral and vertical transfer of basic skills, will be discussed.

Lateral Transfer

Using three different text-editing programs, Singley and Anderson (1989) studied the link between skill overlap and lateral transfer. Secretaries were given a marked-up copy with directions for editing it. Since the skills involved in all three text-editing programs, which differ from typing a marked-up copy, reflected a similar top-level goal structure, a significant amount of positive transfer between the different editing programs was expected. Accordingly, some secretaries practiced typing on one editor and then switched over to another editor. However, other secretaries, prior to learning an editor, practiced typing the marked-up copy instead. Results indicated that transfer from one editor to another editor was indeed significantly greater than transfer from typing to an editor because the same top-level goal representation was shared by all three editing programs.

Singley and Anderson's (1989) skill-overlap hypothesis was again corroborated by comparing transfer from one line editor to another line editor with transfer from a line editor to a screen editor. Because line and screen editors differ basically, different methods must be employed to solve editing problems. Thus, greater transfer was predicted in going from one line editor to another than from a line editor to a screen editor. As expected, there was significantly greater transfer from one line editor to another line editor, based on percentages of time saved. These results,too, suggest that the degree of lateral transfer between skills is directly related to the degree of overlap of the skills.

Vertical Transfer

Basic skills frequently facilitate positive lateral transfer for similar skills. However, simple basic skills are also conducive for vertical transfer because they can positively transfer to more complex basic skills, which incorporate the simple skills.

Gagne and Paradise (1961) conducted a classic demonstration of vertical transfer, which focused on solving linear algebraic equations. In order to identify those simpler skills that might contribute to the lateral

learning of more complex skills, a rational task analysis was performed on the task of solving linear equations. In rational task analysis, a task is logically decomposed into simpler and simpler elements. Activities lower in this hierarchical set-up are simpler than activities higher in the hierarchy. Moreover, these simpler activities are incorporated in the more complex activities to which they point.

Gagne' and Paradise (1961) tested the notion that students' prior knowledge of the lower-level skills in the skill hierarchy facilitates the acquisition of the higher, more complex skills. The results indicated that students' prior knowledge of the lower-level skills was highly correlated with learning speed ($r = .78$) and achievement ($r = .82$). On the other hand, students' vocabulary knowledge, which is highly correlated with intelligence, was only slightly correlated with learning speed ($r = .18$) and achievement ($r = .22$).

Further analysis of each student's data (Gagne' and Paradise, 1961) proved an even stronger form of the skill-overlap hypothesis: lower-level (prerequisite) skills in a skill hierarchy not only facilitate acquisition of higher-level skills but are also necessary for their acquisition. This differs substantially from

lateral transfer, which states that possessing similar skills facilitates the acquisition of related skills. This stronger form of their skill-overlap hypothesis has received further support in more recent research (White & R. M. Gagne', 1974).

Representing some of the skills implicated in solving equations as a production set is beneficial because this representation elucidates the overlap among the various skills. Singley and Anderson (1989), using LISP programming, have demonstrated the soundness of employing production rules as the metric for analyzing problems, which entail vertical transfer.

Strategy Transfer

While the degree of skill overlap between the new skill and the known skill is significant for the lateral and vertical transfer of basic skills,in strategy learning, the strategy user's conscious evaluation of a strategy's effectiveness is one of the preeminent factors affecting transfer.

Belmont and Butterfield (1977) reviewed over 100 studies designed to train different types of learners a variety of strategies, all of which were unsuccessful in obtaining transfer. However, they noticed none of the

students in these studies were required to reflect on the success or failure of their strategy use.

Belmont, Butterfield, and Ferretti reviewed seven studies in 1982 involving strategy training, which did require students to consciously evaluate the success of their strategies. Transfer was successfully obtained in six of the seven studies.

Brown, Campione, and Barclay (1979), as one example of these studies, compared a group of students trained to self-test their readiness for a recall test with a control group which did not receive training in self-testing. Each group was taught an efficient rehearsal strategy. Results indicated that only those students trained to self-test successfully transferred the strategy to new memory problems a year later.

Other studies since this discovery have confirmed the link between a learner's self-evaluation process and transfer (Pressley et al, 1884; Palincsar & Brown, 1984; Bereiter, & Bird, 1985; Ghatala, Levin, Pressley, and Lodico (1985).

Other Factors Impacting Strategy Transfer

According to Pressley, Borkowski, and Schneider (1987), several other factors, in addition to learner self-evaluation, critically impact strategy transfer:

(1) knowledge of when and how to apply a strategy (Gagne, Weidemann, Bell, & Anders, 1984; O'Sulllivan & Pressley, 1984), (2) imputing success to effort and employment of strategies (Clifford, 1984), (3) ability to screen out distracting thoughts (Kuhl, 1985), and (4) degree of relevant declarative knowledge (Chi, 1985; Walker, 1987; Means & Roth, 1988). Like learner self-evaluation, each of these four factors, which has also been shown to influence strategy transfer, will be examined below.

Knowledge of when, how, and why to apply a strategy. Many strategy training programs, in stressing the mechanics of applying strategies, omit two equally important elements: recognizing when to apply a strategy, and realizing why a specific strategy works, including the details of how to effectively implement it. Pressley, Borkowski, & Schneider (1987) refer to these omitted elements as specific strategy knowledge. Gagne, Yekovich, & Yekovich (1993) use the term metacognition to refer to this knowledge of why and how a strategy works; moreover, they maintain that such knowledge forms the conceptual basis for strategy transfer.

Imputing success to effort and employment of strategies. High achievers, in contrast to low achievers, generally persevere when things get rough because they

impute their academic success to their ongoing efforts (Clifford, 1984). Transferring strategies in a novel context would certainly qualify as a trying situation, requiring much perseverance. Transfer, therefore, often requires that students use a variety of strategies in order to determine what works. Only those students who believe that their efforts are instrumental to success will likely transfer strategies to new situations.

Ability to screen out distracting thoughts. When facing new tasks, some students are plagued with more distracting thoughts than are others. However, those who are more efficient at screening out distracting thoughts cease to entertain these thoughts and turn instead to an analysis of what is required for the new task. Kuhl (1985) employs the term, action control, to describe the ability to take positive mental action and to screen out distractions. Kuhl's findings suggest that students, who exhibit high action control, approach study tasks more strategically and are eventually more successful.

Degree of declarative knowledge. Declarative knowledge is a final factor impacting the extent to which some strategies transfer. Such knowledge is instrumental because many strategies require it for their successful implementation. For example, activating one's prior

knowledge, which is relevant to the topic one is reading about, is nearly always beneficial. Doing so enables the reader to generate elaborated memory structures to accommodate the new information being employed. As a strategy, however, knowledge activation cannot be transferred to situations in which the reader lacks requisite knowledge (Walker, 1987).

As another example, Means & Roth (1988) investigated the split-half strategy employed in electronics trouble shooting. An electronics technician, using this strategy, can determine which half of a pathway is exhibiting problems by dividing the pathway in half, if s/he understands the pathway that the electrical current takes through a device. Using only one measurement, the technician can eliminate half of the circuit. Technical schools teach students how to employ this strategy on simple devices and circuits; unfortunately, some of them fail to transfer this strategy in real workplace situations because they possess inadequate declarative knowledge of the complex devices that they typically troubleshoot. Lacking a functional understanding of the device assures that they will fail to locate the halfway point in the circuit. In these situations, therefore,

what is needed primarily is the acquisition of more declarative knowledge.

Instructional Implications

Since transferring knowledge to novel problem situations may be contingent upon an individual's conceptual understanding, it makes sense to ensure that one's curriculum pays adequate attention to the conceptual basis of a problem area. Unfortunately, doing this is more difficult than it appears because the effective conceptual basis of numerous problem areas is not known. Consequently, the wrong conceptual information is taught. For example, technical schools regularly teach physics knowledge as the conceptual basis of electronics maintenance work. However, the conceptual basis of their curricula should focus, instead, on device knowledge, since technicians require a functional understanding of systems' devices and components needing repair (Means & Gott, 1988).

The performance of cognitive analyses of expertise, employing the expert-novice paradigm, is the most valid and reliable method to obtain information about the conceptual understanding essential for transfer in a problem domain. This approach, however, is very expensive; so many instructional designers informally

interview subject matter experts. Relevant conceptual knowledge is identified through think-aloud protocols, derived from experts thinking aloud while solving some novel problems.

Ironically, according to Gagne, Yekovich, and Yekovich (1993), the problem of knowledge activation will still exist, even with a successful solution to the practical problem of expensive elicitation techniques. They suggest that more basic research is required in this area. For example, how do people who activate relevant knowledge differ from those who fail to do so? Are problems represented differently by them? Are they more persevering? In addition, to what extent are the promising instructional strategies of cognitive apprenticeship and anchored instruction effective for transfer?

The validity of skill hierarchies and prerequisite skills is rejected by many teachers because some curriculum materials are rigid and boring for both student and teacher. However, none of this invalidates the overwhelming evidence demonstrating the necessity of prerequisites in various skill domains. Accordingly, teachers should feel free to reject or modify curriculum materials that do not benefit students; however, it would

be unwise for them to reject the notion of prerequisite skill relationships (Singley & Anderson, 1989).

Strategy transfer is typically enhanced if the new task is analogous to a task for which the student has previously learned to apply the strategy. In addition, the new task must be represented in a manner which stimulates thoughts relative to appropriate strategies. How this new task is represented seems to be influenced by at least four factors.

Evaluating the utility of the target strategy is one factor. If this has been previously done, then the student is likely to activate this utility information (Ghatala, Levin, Pressley, and Lodico, 1985).

A second factor is the degree of knowledge a student has regarding why, how, and when a strategy works (Pressley, Borkowski, & Schneider, 1987). This metacognitive knowledge forms the conceptual basis for strategy transfer.

A student's belief that his/her efforts are instrumental in achieving success is a third factor. More specifically, those who persevere are more likely to employ a variety of strategies in order to determine which one(s) work (Clifford, 1984).

The ability to screen out distracting thoughts is a

fourth factor. Students who can screen out such distractions have more cognitive capacity available to analyze what is required for the new task (Kuhl, 1985).

Ostensibly, the transfer of skills and knowledge remains a matter of great interest to educators. It is an issue that has spawned substantial controversy among psychologists. Recent progress on this topic, however, has begun to provide us with a better grasp of it. Nonetheless, there is still a great deal to be learned.

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